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PSYCHOLOGY AS AN AID TO PRODUCTION.

Address delivered before the London Section, 30th November, 1928, and before the Birmingham Section, 5th December, 1928, By Geo. H. Miles, D.Sc.

TO-NIGHT I wish to speak about some of the directions in which the application of Psychology to Production may seem a little remote. I have taken for a start the case of Psychology applied to Lay-out and Routing. Everyone here is aware of the importance of efficient lay-out, and routing. These may be looked upon as aspects of one problem ; lay-out as the static side, and routing as the dynamic side of what is really a unit problem.

Psychology Applied to Lay-out and Routing.

The question arises " How does Psychology come into these problems ? " The Industrial Psychologist looks upon his work essentially as a method of dealing with the reaction of the human being to his mental and physical environment and I would like to stress the fact that the psychologist looks at production problems from a somewhat different angle from the engineer. The engineer is mainly concerned with the material side ; the question of the flow of raw material, time values, transport requirements, etc.

The psychologist looks at the problem from the point of view of the person who is actually placed in that environment, and he tries to arrange the lay-out so as to utilise to the fullest extent the capabilities and the possibilities of the worker. To come down to practical illustrations I will quote one or two cases in which a lay-out has been arranged without sufficient reference to the convenience of the worker.

In a cabinet making works where lay-out and routing had been arranged on the gravity flow principle, the raw material was taken to the top floor and there sawn up roughly and passed down through the chutes to the next floor for planing, etc. After having been cut to size it was passed to the next floor for numerous other operations, then to the next floor for assembly and the addition of fittings, and finally to the ground floor for polishing and finishing the article. This was an excellent plan from the point of view of flow of work—material passed regularly along the shortest route. Viewing it from the point of view of the worker, you will see that the snag was in the fact that polishing and finishing, the essential factors in selling qualities, had to be carried out on the lower floor where for a considerable part of the day artificial light was used. The workers were working under a very considerable disadvantage. The working rate was slow, repolishing was often necessary resulting in a heavy charge on production. We recommended putting the polishing room in the upper part of the factory.

Here is another instance of a similar kind in which the workers had not been sufficiently considered when planning working positions. It was in a factory where fruit was put into glass bottles. In the centre of the room was a long packing belt on which material was placed and passed to the workers. It was found that the intensity of the light on the benches near the belt where the essential packing processes were carried out, was altogether insufficient for effective work. The whole time that room was in use, an unnecessary charge was being put on production owing to the fact that workers had not sufficient light on an important part of the process.

Another instance of a different kind will serve to show how important it is to consider the workers' convenience. We were requested to make a survey of working conditions in a large liner, in the galley, in the scullery, and at the serving places, so that hindrances to effective service should be reduced as far as possible. An extraordinary discovery followed in going over that ship. It was found that in every place where service was required or where handling of china was necessary in the dishing up of meals, the existing conditions suited a left-handed man best. The workers had, of course, accepted the conditions as inevitable, but were working the whole time under great disadvantages. Many of these details may appear to be trifles, but when each man has to work under these conditions during most of his working life, there is an

unnecessary tax on him throughout the whole time, and there is a heavy charge on production. I give these as instances where consideration of the needs of the worker when arranging the original lay-out would have obviated defects of that character.

Elbow Room.

Another point with which I think you will agree is that the worker should have sufficient elbow room. Most of you will have realised at times how inconvenient it is to have a neighbour a little too close, say, in a crowded restaurant. In many factories sufficient attention is not given to elbow room. On machines and at erecting benches and in assembly work, the usual method is to plan so much space for each person, but frequently that placing is done without experience of the type of job. For instance, in one factory front axles were being assembled. Axles were arranged end to end across a bay. A man frequently would have to stoop and get round his work, and when two men were working at adjacent ends naturally one man got in the other man's way. To a certain extent both slowed down, thus reducing the rate of working. The remedy was simple. Instead of having the axles end to end, they were "staggered," giving ample working space at each end, and as a result production was increased and it was found possible to fit in another row of assembling positions.

In another case, the question of elbow room in a new factory had to be considered. The old factory was very crowded and elbow space was altogether insufficient. The first point before proceeding with the plans was to find out what was sufficient working space for each man. It meant studying each job in turn to find out the working area to be allowed for effective operation and planning on facts rather than an arbitrary average. Another consideration which is sometimes omitted is the fact that the material handled also takes up a large amount of room. A worker, for instance, who has to take part of a wing or spar of an aeroplane, and turn round with it requires his working space to be extended considerably if the work is to be done efficiently. If he is going to do efficient work he must have sufficient handling space for easy manufacture of the material.

Transport.

That brings me next to the question of transport. Very many times I have been into factories where insufficient gangway space has been allowed for transit between groups of workers. Again and again material carried in trucks or on trolleys interrupted and hindered each worker as it passed by. This is bound to cause a reduction in the output of each worker and though the amount in itself may each time be slight, when multiplied by the number of times they are disturbed, there is a cumulative effect which definitely lowers the productive capacity of each man.

I would like to say a word or two from the worker's point of view with regard to the methods of transport by conveyor belts and rollers which are being very largely introduced. I was in an American factory some time ago and, on going into the room where they were packing, again and again the attention of the worker was diverted to a large gravity roller conveyor running right across the side of the room. Down that at irregular intervals, boxes rattled, making a noise and causing distraction. In spite of the fact that the workers had been there two or three years they had not completely overcome the tendency to turn when a particularly heavy package of material came down that runway. In connection with all forms of transport of this kind I would like to emphasise the fact that, if possible, it should be closed in so that moving objects do not pass in front of the workers' eyes, and cause distraction. The distraction is really caused by what is called an instinctive reflex. Directly we see anything moving "out of the corner of our eye," there is a tendency to turn towards it. To check this repeatedly causes definite nervous strain.

In one of the Post Offices telegrams are taken to the people who are sending them by means of a roller rope conveyor. A clip fastened to the rope holds the telegram which passes right across the room and goes in front of a desk where a little clutch releases the clip and the telegram is placed in front of a person who is working there. The clip then moves along and takes up another telegram and so on. Many of the workers in this room were irritated by the passing of the papers across the field of vision, and they said that they noticed the distraction more particularly when they were getting tired after a heavy day's work. This is only a small matter for a person who goes into such a room occasionally, but for a person who spends the whole of his life in the place there is a cumulative effect which inevitably reduces his productive capacity. The visual distraction, then, which is sometimes caused by the conveyor system should be taken into consideration in considering methods of transport and in planning the position of conveyors. I think everybody will realise the worker's point of view on this question if they will contrast a shop where individual drive has been put in, with its appearance when it was operated by the usual belt drive. The clear view that is obtained over the whole shop and the absence of the whirring flickering belts makes a tremendous difference. A worker can concentrate his whole attention on the job in hand.

Flow of Work.

Another important factor in production is planning for a smooth flow of work. This is probably self-evident. It is a fact which is emphasized again and again, but I do not think it is sufficiently realised that in addition to the time factors, psychological factors come into play. If the flow of material is irregular it is a question

of time lost plus loss due to an habitually lower working rate. A person whose material is supplied irregularly knows just how long to take over his work, and restricts his efforts so as to meet the irregular flow. An irregular flow tends to lower the average rate of working. Then again, to a smaller degree, there is brought into play what may be called the " warming-up period " ; getting into stride and then falling off which occurs in all shops. When a person tackles a job first of all in the morning, there is a certain amount of time during which the human organism has got to warm up to full activity. If the flow is irregular, it means that a person just gets up to a good production point when the flow falls off, and he has to start all over again. This reduces productivity.

Removal of Material.

Another factor concerns the regular removal of the material which has been produced. When a person is producing a certain number of articles and piling them up in a tray on one side, the tray gets fuller and fuller. There is a feeling " I have done a good bit of work " and a tendency to slack down as the amount which has been made increases. We experimented in a box-making plant. There, of course, congestion soon follows work. The boxes were made at the usual nailing machine. We found that a regular removal of boxes gave a higher and steadier rate of production than periodical removal of accumulations. We had a striking example of the value of not overdoing supplies, in a fruit canning factory. The fruit was supplied in baskets of 1 st. weight, and had to be picked and sorted into grades. We wondered what would happen if baskets containing 7 lbs. were supplied. It would mean more frequent transport, of course. We tried it and we found that output increased 100 per cent. It seems incredible, but figures were taken over a considerable time showing that when the task did not appear so unweildy, it had a distinct influence on those workers' output. In many occupations, as in packing, material is sometimes piled on one side of the worker, who is working more or less in a well, and his activity is to a large extent restricted by accumulated material. That restriction, I believe, from the few experiments we have carried out, has a very definite retarding effect on production.

Balancing Flow.

One point I would like to emphasize is the question of balancing flow. Most people who are in large production works will have been up against this. To balance flow it is necessary to plan production so that all parts come together in the right quantities and at the right time for a regular assembly. It is, of course, essential to get a time study of the whole of the processes. I have been through many places where the flow has been apparently well balanced, but on going into the details it has been found that a department has been working below productive capacity simply

because they knew that if they were to work at full productive capacity they would outbalance other sections.

In most engineering works it is possible to work out production and to time its flow, but even there, I have come across instances where a good deal could be done in balancing up flow. The particular instance I have in mind is in a clothing factory where, in one department, the change from winter to summer clothing production means that the amount of stitching required in putting canvas into coats is much less, and yet the same number of people in the canvas department apparently worked just as hard in the summer as in the winter. But, by starting an entirely new group and timing them carefully on the summer work, it was found that the summer requirements could be quite easily met by half the number of workers. The question of balance of flow is one that is very important from the production point of view, and a constant check is necessary to make sure that each section of an establishment is pulling its weight.

I do want to emphasize the fact that in the question of lay-out, routing, and transport, it is essential to consider the human factor as well as the material factors. If conditions of work are not of the best for the people who will have to work in the places planned for them, then it means that the whole time that the factory is in existence there is a definite tax on production which need not be there. From the material standpoint the plans may be excellent, but if there are points where the reaction of the worker to the lay-out and system of routing and transport is such that he cannot work under the very best conditions, he is penalized and the firm is penalized.

Machine Design.

The next point I wish to talk about is that of the relation between worker and machine. This again is another aspect of reaction to environment. The environment in this case is the machine which the person is working, and I think there is no factory where one cannot find instances where levers, pedals, etc., are awkwardly placed ; where, again, a tax is put on the worker. Probably the worst offenders are the various types of presses which are in use where the pedals are arranged at awkward heights. I have seen, in a factory, instances where girls have had to lift the right foot at least 14 in. from the ground in order to press a foot lever. I am sure it is within the capability of engineers to design machines which do not require such an amount of actual foot movement. Then again, in the engineering world, the position of controls is not always arranged to the best advantage. Just go through a shop and watch the men working. He stoops for something down here —reaches over there, and then stretches up there ! Most of these movements are quite unnecessary if a little forethought were

exercised to get controls close to him. Perhaps a lot of it is due to tradition. I have often asked people why a tram driver should have to stand at his electrical controls and yet a bus driver is given a comfortable seat and his controls are placed in an easy position! Is there any reason why a tram driver should stand? There is another point. This question of controls is not merely one of purely physical effort, but again, probably, a psychological factor comes in. Now consider a man with a rifle, the positions of arms, hands and eyes, and whole body concentrating on the main object! What is required in the case of machinery is that controls are so arranged that there is concentration of attention on the essential object. I feel sure that if machine designers would only consider the matter they would get better production by concentrated attention.

On this question of machine design, I have often said I would like to compel, by law, every machine designer to spend at least a year at pretty lean piece rates on machines that he designed. He might possibly realise that it is worth while giving some attention to control and direction of attention.

Lighting.

Again and again I have had to emphasize the importance of lighting. I was through an engineering works the other day with very excellent overhead lighting, and came across several instances where a machine had been placed so that surfaces were turned away from the light, where most light was required. Workers can be as hampered by too much light in the wrong place as by too little light. If a person has a bright light brought in front of him physiological reflex takes place and the pupil of the eye narrows. Suppose a man has delicate work to do, and there is a bright light placed in front of him. This reflex action takes place, the pupil narrows and very much less light enters from the actual work than is required for accurate manipulation. Thus glare or badly placed lights, even though adequate in intensity, can actually reduce production.

Sufficient attention is not paid to the direction from which the light comes. In fine work particularly, the angle of illumination is often very important and in work, such as cloth examining, both the directions and angle lighting are important. We carried out some experiments in the examining department of a firm in the North of England concerning the effects of overhead lighting, lighting from the right and left hand sides, and there was a marked difference in the results when cloth was examined in these three ways. The cloth is examined six or seven times, and the time spent on examining is a production cost. If, therefore, the time taken is longer than it need be, or if faulty work is passed, production costs are increased unnecessarily.

The colour of light also is sometimes important. In one factory

where brushes were made, it was essential for quality of production that only pure white bristles should be used. Girls were therefore employed to examine the bristles, sorting out those which were yellow. By using green backgrounds which reflected light the yellow bristles showed up plainly and it was possible for the girls to select more rapidly and accurately. Similarly the use of coloured light assists in the work.

Another factor which is almost entirely overlooked by lighting experts is the difference in intensity of light on the working point as compared with the general illumination of the working area. If a person is working at a point which is brightly illuminated and then turns to pick up another tool situated in a less well illuminated position the eye has to adopt itself to the change in a fraction of a second ; if the difference in intensity is too great it simply cannot do it ; the worker loses time and is irritated by the delay and repeated strain. The use of spotlights and insufficient general lighting is therefore a definite check on production.

Many firms have given much attention to artificial illumination but have neglected natural illumination though work done under natural illumination occupies by far the larger proportion of time. The Institute has carried out experiments with daylight illumination which show that an improvement in production of as much as 20 per cent. can be obtained by giving careful attention to the problem. When changing from natural to artificial lighting there is generally a slowing down in production rate. This may be due to the fact that when a person is working during the day at one position he gets used to certain shadows ; the artificial lighting comes from a different direction altogether and if it is of a bad type the shadows are accentuated and a certain amount of adaptation is necessary during the change. After a time the worker becomes used to the altered conditions and his production rate increases. This seems to suggest that experiments should be made to ascertain whether the transition cannot be effected more satisfactorily by so placing the artificial light that there is a less marked difference in incidence.

Rhythm.

Another point affecting production is the speed of the machine in relation to the normal rhythm of the worker. I had my attention drawn to this problem very clearly in the case of a stitching machine. A man was at work stitching boxes, which required a stitch to hold each corner. He kept his treadle down during these four operations, and turned the box so quickly that each corner was in the correct position for a stitch at the right time. This he did very well until about the nineteenth or twentieth box, and then he would get two stitches where only one should have been, and had to stop and take out the unwanted stitch. His natural rate of work was just under

the rate of stitching of the machine, and we found, that by reducing the speed, a false stitch was only seldom made and a 10 per cent increase in production followed. Cases such as this emphasize the problem of the selection of workers.

Selection of Workers.

The selection of workers requires much more scientific study than it did ten to fifteen years ago. Then the usual method was to interview them and allocate them to various jobs. That was in the days when the degree of specialisation was by no means as great as it is at present and all-round ability could satisfactorily cope with most jobs. Under modern conditions, the need for selection of human material is quite as great as the need for the selection of the raw material. No one would ever think of using steel of an unknown quality. Yet again and again workers are taken on with very little attempt to determine what job they are best fitted for.

It is still possible in some occupations, as in a retail store, to sum up in an interview a person's general suitability, but when it is necessary to determine a man's ability to work with his hands, such a method is useless. There are, however, now in use a large number of tests which in practice have been proved to give better selection than can be obtained merely by interview. Possibly Germany has gone ahead more than any other country in this direction. In a number of large works, for instance the A.E.G., at Krupps Works in Essen, and at Philips' lamp works at Eindhoven, they have numerous tests for selecting workers and have set apart a laboratory and have developed a testing organisation. As the candidates pass through the tests, their suitability for a particular line of work is recorded on their cards and if possible they are placed in that particular job. The results that are coming to hand, after five or six years, show very definitely that they are getting workers who are more efficient at their work and judged by the reduced labour turnover, are more contented and take a greater interest in their work. Tests, however, are by no means infallible, but in the long run they do give a better selection and definitely assist in gauging more exactly a man's capabilities. Another fact there is, it is essential not to select a man who knows his job very well. You very frequently find that a good worker is so expert that he does not realise what are the difficulties that a beginner comes up against, and tends to become impatient. Further, he probably is incapable of explaining just where attention should be directed. Such hints make all the difference between good training and poor.

The Institute has devised selection tests for many firms in this country and though at this stage it is difficult to get exact figures of their utility, the testimony of those who are in daily contact

with the selected workers show unquestionably the value of the methods. Thus one firm says, " We feel confident that if you are able to supply employers with tests of equal merit to those you have supplied us with, the Institute will not only be of the utmost value to employers of all kinds, but will also render an invaluable service to the nation and humanity as a whole."

Discussion, London Section.

MR. JAMES G. YOUNG (Chairman) said he knew of a case in the Manchester area where the colour scheme had been changed so far as the walls were concerned and there had been an increase in production. He asked the author to what extent the use of shades for workers, provided by the employers, was developing. On bright work the workers should certainly have " blinkers " to suit the conditions. All this was allied to " safety first," which was worrying everybody to-day as there were more killed in factories in this country on the average than there were in France, and we could not go on slaughtering one another in this manner. The problem of rest periods was one of special interest to the production engineer whose job it was to get the work out in a given time.

DR. MILES said the National Institute had been approached many times on the question of shades and an important point was to see that they were comfortable. He mentioned instances in which shades had been discarded by the workers on really dangerous work simply because they were not comfortable. In the same way, as regards accidents, guards were often placed in quite the wrong positions, although the guards, as such, were quite efficient. Cases were mentioned in which guards were fixed in positions which proved a hindrance to the worker, and this was a drawback in the case of piece work and often led to the guard being put on one side and accidents happened. Rest pauses were very effective in the case of handwork when a pause did not mean the slackening down of a machine. With machines, of course, the object was to keep the idle time down to the minimum and in such cases it was necessary to arrange the workers in relays so that the machines were not stopped or output reduced through loss of productive time. The general effect of rest pauses was not so much an increase in output—usually it was about 5 per cent—but they had the effect of levelling up the curve towards the end of the morning or afternoon spell and improved the quality of the work because the operators were less fatigued. They also seemed to improve the morale in a room or shop. He mentioned a case in which games were introduced during the rest pauses and in that case the output went up by 15 per cent. This was a case of girls doing embroidery work.

Colonel Rudd, in congratulating the author, said he had laid down what might be called common-sense principles applied to engineering production. As regards colour, he remembered reading an article in the *British Medical Journal* some years ago on the wonderful rejuvenating effect of primrose yellow, and he had tried it himself. He had some machines painted yellow and everybody roared with laughter. It was only an experiment and he had not been able to carry it any farther. Could the author give any information as to the effect of colour in relation to different operations on different machines? Also, how far had psychological tests been applied to craftsmanship, as at the moment he was engaged in training craftsmen?

Dr. Miles said he was afraid he had been asked two questions he could not answer. He was not aware of any scientific work having been done as to the effect of colours upon machine shop operations; a great deal of experimental work had been carried out but the results were too indefinite to base any definite conclusions upon. The Institute had often been asked about this question of colour and was perfectly willing to carry out experiments. In the same way, not a great deal had been done in this country with regard to psychological tests for craftsmen and students. In one case, the children attending a certain school—600 in all—had been divided into two groups, one group being tested and put to work which it was thought they were best suited for, and the other group being allowed to take up such work as they pleased. It was difficult even so to arrive at definite conclusions although it was felt that encouraging results were being obtained in as much as those students who had taken up the work advised by the Institute had changed their jobs less frequently than the others and the employers were more satisfied with their work. This particular test was still being carried out in connection with the particular school, as the children reach school-leaving age.

Mr. Butler asked for information as to the type of lighting most suitable. He had in mind engine turning operations on fine metals where there was a very bright reflected light from the work which was very trying to the eyes. He had tried several methods, including coloured globes and shades, but eventually it was found that the daylight lamp was the best for the purpose. The peculiar thing, however, was that although these daylight lamps had a much greater candle-power, the workers did not seem to be able to see so well. They were, however, able to work more comfortably. The mercury-vapour lamp seemed to be very popular in some shops and he was wondering whether there was any psychological effect due to the colour or whether the beneficial effects were due to lack of eye-strain.

Dr. Miles said he had no definite statistics of the kind asked for by Mr. Butler. The Institute had experimented with mercury

vapour lamps in connection with sorting screws and it was found that whereas ordinary lighting put a very definite strain on the workers the mercury-vapour lamp did not. The girls, however, strongly objected to the colour of the light given by this lamp. As an instance of psychological effect, he mentioned that when the light was replaced by ordinary lighting again one of the girls had refused to go into the room because she still thought the mercury-vapour lamp was there, she having got the colour so fixed in her mind, so to speak, that she had failed to realise a change had been made. It was an interesting example of the way in which things re-acted upon the workers. In experimental work it had been found that the mercury-vapour lamp resulted in an increased output of from 5 to 6 per cent., and it had been recommended to the particular management. He had heard no more about the matter and it was an unfortunate fact that investigations were often carried out at some expense to a firm and the recommendations were pigeon-holed. There was a very large installation of mercury-vapour lamps in the printing premises of the *New York Times*, and where this light alone was used it was usually satisfactory. The trouble generally came when the lighting was mixed. The daylight lamp had been experimented with considerably for colour matching, and it was an improvement, but the disadvantage was the high cost of current owing to the large consumption. The problem of reflection from the surface of the work must be studied from the actual working places and from the worker's position. A great deal required to be done in connection with the ratio between the intensity of illumination at the working place and the intensity of the general illumination. In one instance, there was a very high intensity of illumination on the machines and a very poor general illumination, so that the workers went into relatively semi-darkness when they looked away from their work. That was changed, but then it was found that although a very high general illumination had been installed the lighting on the work was insufficient. The remedy was a mean between the two and the original spot lights for the machines were reinstated with a better general illumination.

Mr. Salmon, speaking with regard to the point mentioned by the author that an increased output was obtained by polishing certain cabinets on the top floor instead of the bottom floor, even though this interrupted the straight flow of the operations, said he could not quite follow the point. His experience was that cabinets polished at the top of a building were passed when they would be rejected on the bottom floor owing to the different lighting shewing up defects in one case which were not so noticeable in the other.

Dr. Miles replied that this was another of those cases which demonstrated the importance of studying the matter from the worker's point of view. In the particular case, the lighting

conditions at the top were such that better work was turned out, and more quickly, owing to the fact that there were not so many reflections from the polished surface and the number of rejections was less.

Mr. Gartside asked whether any investigations had been made concerning the effect of noise upon output. He had also read that the introduction of musical instruments assisted output in certain cases.

Dr. Miles said that the question of introducing musical instruments during working operations was related to the problem of rhythm and it had definitely been proved that in certain operations rhythm played a very important part. If the operators could be induced by some means to impart a rhythm to their work, the output invariably increased, but, of course, it did not apply in every case. He had no information as to the effect of noise on output. As a matter of fact a request came into the Institute the other day for a lecture on the effects of noise but it had to be turned down because there was no available information of a reliable character to go upon. He did not think there was a great deal to be feared in the ordinary way. In weaving sheds it was impossible to hear oneself speak, but the girls practised lip-motion and apparently found no difficulty either in getting on with their work or carrying on a conversation.

Mr. E. D. Ball (Hon. Secretary) asked if the author had any comparative figures showing the effect of rest pauses as against changing the occupation of the worker from time to time. He came across a case recently in which girls were engaged in examining highly polished steel balls directly under a powerful light, and he was told that they had no rest pause although the foreman was thinking of introducing one. After looking at the balls for two or three minutes he found his eyes were watering, and it seemed a definite case in which the girls should not have done that work for more than an hour at a time. It seemed quite easy to give the girls a rest and to arrange for others to take their places whilst they were put on other work.

Dr. Miles said that experiments had been carried out in connection with rest pauses and as he had already mentioned there was not a big increase in output, about 5 per cent., but there was a better feeling and a better tone throughout the workshop, and rest pauses were well worth while. It was difficult sometimes to induce piece workers to take rests because they felt they were losing money, or they would rather go without the rests and finish their jobs and get home so much earlier. In many cases, therefore, he would be in favour of what he called change pauses which had the effect of giving a total change of occupation for a few minutes without affecting the continuity of the operations. As an instance of this he mentioned a case in which girls came in in the morning

and had to go to a certain place to obtain a supply of work to start upon. He found that by making the girls obtain their supplies in the middle of the morning and afternoon, the short walk to the giving-out place had the effect of a rest pause, and output was slightly increased because there was not that feeling of fatigue which usually came towards the end of the morning and afternoon spell. The girls left a supply of work on their tables before they went home at night and they started on this the next morning. In some occupations a rest pause was not necessary, but in others a change of posture was a great advantage. In a certain polishing operation, the men at first were always sitting in a position which became very tiring, but a new bench was designed which necessitated the men getting on to their feet for the final polishing, and this change was a great improvement all round. Incidentally, Dr. Miles urged that a fair trial should be given to new schemes. He instanced a case in which an improvement was applied only to half a shop, the old method being retained in the other half. Then the output of the whole shop was taken and the new idea was said to be a failure. That was not a fair way to deal with these matters.

MR. SALMON asked whether something had been found to take the place of blueprints. These usually contained a large number of dimensions and after they had been in use for a short while were very troublesome to read.

DR. MILES agreed that the condition of blueprints in many engineering places is a disgrace. They were often badly printed in the first place, and after a short while in use were most difficult to decipher. It was a harsh penalty to put on the men, and also a false policy because of the waste of time involved.

MAJOR RUDD remarked that instead of blueprints it was now possible to obtain papers known as ferrogallic and ozalid. They were a little more expensive than the ferroprussic or blueprint paper, but they gave very much better results. It was possible to trace from ferrogallic paper as it was a dry printing process developed by ammonia and there was no appreciable expansion or contraction. It was possible to get an almost true to scale print which could be used as a negative for printing.

On the motion of MR. BUTLER a hearty vote of thanks was accorded Dr. Miles for his paper.

DR. MILES, acknowledging the vote of thanks, spoke of the reaction of the surroundings upon workers and the need for watching their effects. It had even been found that the Institute's investigators tended to become affected by the surroundings in which they were carrying out their investigations and it was sometimes necessary to change them. Managing directors and works managers had so many other things to look after that they could not give the time to a concentrated study of what might appear at first sight to be insignificant details. Therefore, it was necessary to find somebody

who could give undivided attention to them and experience had proved that it was profitable in the long run. The great thing, however, was to be able to carry out these investigations with the co-operation of those concerned. Once there was suspicion, that was almost a finish to everything.

SOME IMPRESSIONS OF ENGINEERING WORKS IN THE UNITED STATES.

Presidential Address by Mr. J[redacted] A. Hannay, Annual Meeting, Birmingham Section, January 9th, 1929, at the Chamber of Commerce, Birmingham.

MR. J. A. HANNAY, President of the Birmingham Section of the Institution, said that he went to America as a production engineer to look at everything from a production engineer's standpoint. Having given his impressions of New York and of a short visit to Niagara, he next referred to his experiences in Detroit. Detroit in 1900 had a population of 285,000 and in 1928 it had 1,800,000. Seventy-five per cent. of the automobiles made in America were made in Detroit. Ninety-five per cent. were made within seventy-five miles of Detroit. It had 2,200 manufacturing plants, fifteen truck and auto plants, one hundred and fifty auto accessory plants and one hundred and thirty-three chemical companies, turning out one hundred and fifty million dollars' value per year. There were many buildings 25-40 storeys high, including General Motors building and Fisher building. These two buildings were entirely erected out of the production earnings in the automobile industry.

As regards the automobile factories he found two schools of thought. One believed in rating the plant below the maximum capacity, 15 or 20 per cent., to cover breakdowns. The other rated the factory at its maximum and then they had other plant available for breakdowns—good machines capable of being used on any class of work.

Amongst the factories he visited were Packard, Cadillac, La Salle, Dodge, Chrysler, Buick, Hudson-Essex and the Ford. He gave them in the order as stated. Ford was the most crowded of any, with the Hudson-Essex next, while Packard was the most roomy, followed by Cadillac. He found the Cadillac factory covered fifty odd acres and was mostly four-storey buildings. The plant was laid out some few years ago to accommodate an output of 100 cars per day. The capacity was now about 225 per day and he should estimate it would rise to 500 per day without any further building being required.

Cadillac and La Salle engines were made in one factory—eight cylinder "V" engine—most parts interchangeable except vital engine parts. This factory bought all its stampings, frames, etc.,

whilst they made the complete engine, axles and gear boxes. They had their track which holds about thirty-nine chassis and was cleared about three times per day. The La Salle was erected in a separate factory. They kept about three days' supply of engines, gear boxes, etc., and nearly a week's supply of frames, ready to feed the works. The body-mounting shop was something like 650ft. long and very wide. One outstanding feature was that no body was mounted on a chassis unless the production manager held a sales order and despatch instructions. They had a very large tool room, practically all employed on upkeep. The engine track carried the operators with it. They did their operation and then stepped off and went back to the next stage. This firm ground all the gears in their gear box. They made a practice of copper-plating their work before carbonising, turning off the copper where they required it to be hardened. They had several very clever, almost automatic, welding plants. One rather notable feature of this factory was that they had an engineering professor. At five o'clock every Monday night he lectured, and all foremen were supposed to meet and attend these lectures.

Chromium-plating was also carried out there. After polishing the shell of the steel radiators, they copper-plated it ; .001" deposit, taking thirty minutes. They next nickeled it (forty-five minutes) .0005", then gave a wash of chromium for one and a half minutes. They did not understand the testing of engines as understood in this country. They made their engines big enough and ran them in to free them.

He visited the Timkin Axle Company. He did not know a factory more nearly approaching English firms in relation to quantities. He was interested to see their lay-out, but was disappointed in the shop in general. He should say they muddled along pretty much as we did in this country. The plant there was almost entirely British made, by David Brown and Sons, of Huddersfield, 50 per cent. of which was sent out in 1912. They were of the opinion that no machines could do the work as well as the English machines. It was an eye-opener the way the steam hammers work and was well worth seeing. They made rear axles for coaches that ran across the Continent. The billets for making these axles weighed 750 lbs. each, and they made the complete axle stamping in one piece. Front axles were stamped in one minute. The heat treatment department was a very good one, using continuous electric furnaces.

Whilst on the question of forging, he was interested in the die blanks they used in America, a blank that was already hardened or was made just hard enough so that it could be cut—and required no further hardening. The Hepponstall forge works were in Pittsburgh. They also had an office and warehouse in Detroit, on the riverside, with a manager and two university-trained assistants

who kept watch over all the forging and stamping plants about Detroit, ready to advise and render help.

The Buick people produced 1,200 to 1,300 cars per day. Their assembly shop was once a railway dock between two large buildings. There were now bridges between the upper floors and work was fed down through chutes to the tracks. Bodies were supplied by the Fisher Company and it was wonderful to see a specially-coloured chassis coming along the track and a body of exactly the right colour dropped on to it. It was also very interesting to see cars going away. Apparently they were not tested, just driven from the track and put into the trucks by means of a bogie; 1,250 to 1,300 cars per day were assembled by 1,370 men. Their press shop was interesting, especially in making wings or "fenders." Long tracks, such as were used in this factory, enabled such parts as nuts and bolts to be stored easily and readily. Certainly the American people believed in long tracks and making everything as easy as they can so as to get a good speed. He could not remember seeing the floor littered with nuts or bolts, etc.

Another interesting plant, the Hudson-Essex, had three tracks and could produce 1,800 cars per day. They told him that in one week they engaged 5,000 people, when they had a rush. The tracks and operators seemed to be better timed here than in any other place he had visited. The bodies travelled at about twelve feet per minute. When the chassis was built it was lifted up through a hole in the ceiling to the floor above.

The manager told him that, years ago, they had many breakdowns and were in serious trouble. Finally they made a practice of recording where these breakdowns occurred and, sending for the makers of the various machines, pointed out the troubles experienced and asked them to make them good or they would write them off their list. They had a machine for practically every operation and, in addition, they had 200 machine tools all ready to be used in any part of the factory. In the case of drill presses, in twenty minutes they could have another press at work that would do the job.

Now as to rates that were paid. A man starting at the Ford was paid fifty cents per hour. In sixty days, if they kept him, they paid him sixty cents, and if he made himself competent he rose to seventy-five cents. Packard started at fifty cents to fifty-five cents and raised to about seventy-five cents. In nearly every case, group piecework instead of individual piecework was employed. In the Hudson-Essex works they had a fixed rate for each group. Packard had about 12,000 workpeople including about 1,000 women and the works were divided into ninety groups.

About 50 per cent. of the automobile factories were using women. It was also definitely arranged there that the women took about the same proportion of wages in relation to men as in this country.

In some cases inspectors were included in the piecework group. As to the general proportion of direct and indirect labour, he was told that in one factory it was 52 per cent. productive and 48 per cent. non-productive, and in another factory fifty-fifty. One could get anything on the hire-purchase system, and regarding scales of discount on the smaller and less expensive model of one of the best cars, the discount was 25 per cent. Most expensive cars allowed agents up to 40 per cent. At the Packard, employees of five years' standing were allowed to buy a car at 25 per cent. discount.

In the event of production exceeding sales, there was not much difficulty in obtaining sufficient trained labour when restarting. They quickly went on to short time—cut a day or two days out—and then shortened the day.

The general proceeding with regard to manufacturing or obtaining tools for new models was that they made all they could, or bought all they could, almost regardless of cost. The one factor was to get the tools in time.

As to the Ford works, he had expected great things. Speaking generally, he should say that the Ford was the most disorganised factory he had seen in comparison with what he had expected. There was more material about the floor and it was less easy to see how things were going than in any of the other factories. The press shop was very congested and, for the people that did not know it, almost dangerous. They are so concerned about getting output (between 5,000 and 6,000 cars per day). Although there was a big demand for tractors, all tractors had been cleared off. The whole plant, material and everything, had been shipped to Cork. There were six vessels starting on their way to Cork when he was there. Although the inside of the works seemed so crowded, the roads round about were wider than any of our main roads. There was a railroad and something like seventy-five railway engines, all looking as new.

Chrysler were not very busy and were preparing their new models. One thing noticed about their factory was the very large number of engines and components stocked. The Dodge, to his way of thinking, was the most mechanically laid out factory he had seen. When he enquired about Dodge, he was told that the Dodge brothers were instrumental in organising the Ford works in the early days and finally broke away.

He visited the Dominion Forge, at Windsor, on the other side of the river, where they were making parts for the Ford in Canada, but compared with the leading twelve stampers in this country, their work was very poor. This firm was turning out, a fortnight before he was there, 350-400 tons of stampings every week. They were told to shut down to about 150 tons. They quickly ran up a stock of 10,000 tons of material which was being delivered and which they could not stop.

At the Armco sheet steel rolling mills they had twenty-four men called "routers" studying manufacturers' requirements, so that if any trouble cropped up there was somebody standing by to try and help them. These people had bought a factory about ten or twelve miles away from one of their rolling mills. They placed a railway line from the blast furnace, nine miles away, to the mill, and supplied molten metal from blast furnaces to mill, fifty tons at a time. He saw there big ingots about five tons in weight. These were rolled out into slabs of about one-third their original thickness, went into a muffle and from this muffle one was carried into a rolling mill and rolled, then another one, and so on. It came out in one long sheet 250 feet long and was then rolled on a spindle and carried to a storing room, one ton per minute. When their engineers suggested this process of continuous rolls, it meant an expenditure of eight million dollars. The principals knew that if it were a success it would be a good thing, and that if it were a failure it would cripple them for years. They trusted their engineers, and they had now got three mills going and were very prosperous. The foundries were wonderful. Some of them were almost automatic. Finally, American salesmanship. Wonderful! They got the information on whatever they wanted into the works months beforehand.

From what he had said they would conclude that he considered that the Americans were good. They were well organised, but with all respect to them, he still believed the Englishman, taken all round, could do better.

Discussion.

Mr. W. G. Groocock said he was sure that he was voicing the opinion of everyone there when he said that they had been deeply interested in Mr. Hannay's address. He would take first the reference that Mr. Hannay had made to American salesmanship. One of the American methods of promoting salesmanship was to have holiday camps. They divided their executives into three groups, directors and various officials, engineers and members of the sales organisation, and minor shop executives and junior engineers. When each of these groups was at a camp some of the directors were usually present. In the morning they discussed and read papers on technical matters and they had sports in the afternoon. In this way a lot of propaganda was introduced. Another thing he found was the love of conventions and conferences. Also, it was quite a change to be met and welcomed and shown round. From the smaller American works they in England had little to learn. In their large works where mass production was the rule, one came to the conclusion that the methods in vogue had been forced on them by reason of the quantities. He ventured to say that they did not work harder than our people but they worked

more continuously, which gave them a better output per man in most cases. He had had an opportunity of visiting works where turret lathes were made and did not think their methods were nearly so good as those he had seen when going through similar English works. He had also visited a plant making grinding machines and considered that a well-known English plant was run as well, if not better. A plant making drilling machines was another place visited and there again, except in the matter of quantity, England had little to learn. Tendencies in design over there were taking rather a change. Motor drive was being applied pretty generally, but not as it was here. They had three, four and often more motors on one machine tool. Hydraulic feeds were more common in America than here, also the fabrication of big frames which at one time were always cast but now being done from steel sections, etc., welded together. Where repetition was going on they claimed that they could, by this method, make small pieces quicker and cheaper than they could cast them. His view was that American factories, speaking generally, were more up to date than ours. America had a great future in front of it. Its present prosperity was not solely due to its large home market ; they paid high wages so that people could have a larger spending power, and so they were circulating the money much quicker.

Mr. G. J. Morgan said he felt like one of the Three Wise Men of the East in going to America with Mr. Hannay. One thing that struck him very forcibly was the immense amount of capital that American industry had behind it. He wondered what Mr. Hannay's reply would be if his directors came to him and said, "Here is two million pounds. Spend it for us." He was certain that it would so reduce production costs, that every member would be coming to these meetings in an Austin—they could not afford to walk ! Then again, when the Americans made a product, they did not go to anybody and say, "Will you have this ?" They made them have it. He did not want anyone to be lured by the wages that had been mentioned. Though they appeared high to us, it must be remembered that one had to pay dearly for most things over there.

Mr. E. W. Field, on the question of water-power, said that it seemed that America had taken the opportunities which nature had presented while we had not done so in this country. The question was purely an electrical question.

Mr. H. C. Armitage said that the problems we had to face in the next few years were very largely the problems that had already been faced and solved in America. He had always looked on the Ford as an exceptional organisation. Most Americans spoke of the works as being on a very large scale. Was it the case now that Ford was decentralising ? Apparently Ford employed women in only one works. Was that because of economy or was it that they

were found more capable in some directions? The wages, relatively to the cost of living, did not appear to be very much greater than wages in this country. There was no doubt that if you increased the earning capacity of all your producers the non-producers such as policemen, municipal officials, etc., would also have to get higher wages. In its turn this would have the affect of adding to the cost of production. And yet there was little doubt that there was a higher state of prosperity in America than here. America had started industrially much later than England, but she had gone ahead rapidly and we would have to see to it that we were not left behind.

MR. E. J. WILEY remarked that in some cities in America he understood that women labour was not allowed. Certain other cities allowed them to work at jobs at which they could sit down. Perhaps that was the reason why women were not employed as extensively in industry in America as in this country. Where the type of work was suitable he thought that women became quicker and better operators than men at many jobs.

MR. HARRY AUSTIN said that its capital wealth played an immense part in America's success. The cost of electric power had been mentioned. At Niagara, it was one-quarter of a cent for manufacturing purposes and six cents for domestic purposes. Electricity played an important part in American production.

MR. E. G. LATTY said that after listening to Mr. Hannay's address he felt that Americans had a distinct advantage over the Britisher in the amount of standardisation. He did not think that we in this country had really yet got down to the base line of production. It struck him that a useful paper to present to the Institution would be "What is Handicapping British Design?" He felt that the base of production was design and that lack of standardisation was interfering greatly with our production. Comparing American practice and referring to Ford in particular, it was accepted that before proceeding into production, the model was well tested and a definite programme decided upon. He had worked in a number of motor car factories in this country where models were put into production long before the design was finally settled.

MR. STRICKLAND said that Mr. Hannay had referred to him as an American, but he was an Englishman who had been ten years in the States with Ford. He could assure them that it was the salesmen of American engineering who were making American production. In his view they were just as bad in America regarding standardisation as in this country. Standardisation took place when the thing was produced, not before. The design was brought forward to meet the desires of the customer. The production engineer had to re-hash the design so that the car could be produced economically. That was one of the features that had made the success of the American automobile industry. Some of them

had spoken of lack of capital in this country. Ford had had no capital! All the motor industries started in that way. They concentrated on making a market for their products. Mr. Hannay had given them a bright, full and truthful description of what he had seen in the States.

Mr. Hannay replying to the points raised in the course of the discussion, said that as regards salesmanship, to which Mr. Groocock had referred, the Hudson-Essex sales director told his works six months ahead what he wanted. Three months later he confirmed that and ten days before the end of the month he issued his detailed specifications. Packard made up their programme five months ahead. Special models required sixty days' notice. Mr. Field had spoken about the American advantage in water-power. It was not all plain sailing there under that head. At Niagara two firms were absolutely broken before a third stepped in and reaped the profits. Mr. Armitage was under a misapprehension in thinking that Ford was decentralising. It seemed to him that, on the contrary, Ford was centralising and that the cause of much of the congestion which he saw there was due to that fact. On the question of women labour, the Americans had a very great respect for their womenfolk. There were practically no domestic servants to be obtained, coloured people doing most of that kind of work. Mr. Austin had mentioned the great wealth in America. There was great wealth, but it had been earned, and we in this country would have to earn it also, if we were to have it. As to design, Mr. Strickland had said sufficient on that point.

THE DESIGNER VERSUS THE PRODUCTION ENGINEER.

Address delivered to the London Section of the Institution, 83, Pall Mall, London, January 25th, 1929. By Mr. L. H. Pomeroy (Member).

MR. L. H. POMEROY said the title which had been given to his lecture, namely, "The Designer versus the Production Engineer" was a little inadequate and it would be almost as illogical to refer to the architect versus the bricklayer. The subject he would talk about, however, was the relation between the designer and the production engineer. In reading the engineering literature one could not fail to notice a tendency now-a-days to magnify names. In America, for instance, they spoke of the domestic engineer and the railway engineer. Over here, however, we called the railway engineer a locomotive driver which was perfectly correct and not so high falutin. He felt that this question of names deserved a little consideration from the engineering fraternity in general and particularly by the Institution of Production Engineers, because he had heard from some of those present that evening, statements which would make anybody a production engineer. He had even heard a very distinguished newspaper proprietor referred to as a possible production engineer. In a sense, that might be the case but not in the sense in which the members of the Institution of Production Engineers should really understand the matter. According to the Articles of Association of the Institution of Production Engineers, the business of the production engineer was defined as that of promoting the science of engineering and to raise the status of engineering as applied to production, but as he had stated twelve months or more ago at the annual dinner of the Institution, he could not help feeling that this was the wrong way about and that the objects of the Institution should be to promote the science and practice of production as applied to engineering. The function of the designer, whether in relation to a marine engine or a motor car, was to design an article suitable for the market in which that article was to be sold, whilst the function of the production engineer was to produce that article according to the intentions of the designer. By designer, he did not visualise some young gentleman who worked on pieces of paper thirty-six inches by twenty-one inches or whatever the standard size was, but someone who could really decide what the product was going to be and who was capable of making that big guess which all businesses must risk in deciding whether they were going after this, that or the other class of market. Business was a funny thing, because a lot of people imagined they were in business for some secondary motive, but in his opinion, the only reason people were in business was to make money and there

was no other reason. Business was simply the relation of money expended to money obtained—it was a lamentable state of affairs possibly, but people in this world only got what they were worth. Therefore, it became of some interest to examine what part the various functions concerned with manufacture played in the total cost thereof.

Some years ago an investigation was made in America as to the relation between the cost of labour and the cost of material and it was found that for a very wide range of products the cost of material was about four times that of labour. It was a curious thing that this applied even to an aluminium casting. Therefore, it was found that this sort of balance sheet applied in manufacturing operations, labour was roughly 10 per cent. of the total cost, although it might vary between the range of five per cent. or 15 per cent. Overheads were roughly 15 per cent., material 40 per cent., selling costs 25 per cent. and profit 10 per cent. In the motor car trade the two items upon which any impression might be made by way of reduction were labour and overheads, which together amounted to 25 per cent. Again, this might be a little more or less, but it was a reasonable figure to keep in mind. About half the overhead charges consisted of salaries of doorkeepers, cost clerks, jig draughtsmen and other intellectuals and the remainder between electric light, heating, giving the factory walls a coat of whitewash periodically and so on. This gave some idea of the money scale of the operations of the production engineer.

So far as the designer was concerned, he was responsible for the fact that his production must be saleable and the complaint which he proposed to adumbrate in the course of his lecture was that the business of the production engineer should be to see that the designer had more facilities for working his evil will than he had at the present moment, and he proposed to endeavour to describe the way in which the production engineer could be of very great assistance to the designer. Although the principal point which he proposed to illustrate might constitute but a small section of the duties of the production engineering department, he regarded that as of such importance as to warrant being dealt with fairly fully.

His experience of engineering taught him one thing, namely, the importance of the study of local stresses and stress distribution. Most engineers cheerfully agreed about that. He had never found a production engineer who did not agree nor had he known one, however, who was prepared to put his agreement into practice, but it was of such importance that he proposed to talk about it at a little length. The first example was one which he first noticed in connection with some work done at the National Physical Laboratory by Dr. Stanton on the subject of fatigue resistance of steel bars. The Stanton testing machine was one that applied alternating tension and compressive stress to a specimen screwed into the

jaws of the testing machine violently. The specimen, originally, was roughly a quarter of an inch diameter and the threads five-sixteenths inch diameter. It was found necessary, however, to increase the threads to half an inch diameter before it could be quite certain that when the test piece broke, it broke through the plain part of the section when applied with discretion. When it was realised that there was more or less four times the area in this screwed part that there was in the plain part in order to make sure that the specimen broke in the plain part, the importance of the localised stresses which occurred in screwed parts would be appreciated.

During the last twelve or fifteen years a great deal of attention had been given to this matter of stress distribution and local stresses. Notable consideration had been given to the optical method of stress analysis in which by straining celluloid models and passing polarised light through them it was possible to visualise the concentration of stress. He always told his draughtsmen and designing staff that the worst thing that ever happened to the engineering industry was by the man who invented a pair of compasses. It was true that we must have compasses to make holes for bearings because of the impossibility of running a square shaft in a round hole. It was possible, perhaps, to run a circular shaft in a polygonol hole fairly well, but if he were a sort of emperor of engineers he would have a bye-law which stipulated that after the compasses had been used for the holes of shafts they should be thrown straight into the ocean until the job was finished, because what was necessary to design was the architectural instinct. This was much more far reaching than it looked, because it meant that when stress distribution was really studied then we were beginning to get to economy in weight. He believed it was Kipling who said that everything that happened to man from the time he was born to the time he came to his grave depended upon the transportation of mass through space—and he felt that that was very true. When the day came that engineers began to understand the importance of stress distribution and then could persuade their production engineer friends as to its importance, we should not have the production engineering staff going into hysterics because the small end of a motor engine connecting rod has a parabolic profile.

It was necessary, however, also to consider a very important class of member in engineering generally, namely, that which transmits torsion. A shaft, of course, looked a simple thing. It had length and diameter. Sometimes it had a hole through it and sometimes it had not, but it was interesting to consider what happened when a shaft which was of ductile material was twisted. If a plain section of a circular shaft was twisted, it remained a plain section. To that extent a circular shaft was unique and a tubular shaft did the same thing, but as soon as we got away from

the circular shaft, we got into trouble when dealing with torsional stresses. If we took an elliptical shaft and twisted it, the major stress was at the extremes of the minor axis and the minor stress was at the extremes of the major axis. Moreover, when such a shaft was twisted the section did not remain plain. There was a warping of the cross section. Similarly, when a square shaft was twisted there was a warping of the cross section and, in fact, any shaft which was not a circle, for instance, a spline shaft, produced a warping of the section which entirely upset the stress distribution. Moreover, that was not the worst of it. If we took something well known in engineering, namely, a shaft with a conventional key-way in it, as soon as it was twisted, then by all the mathematical laws of elasticity, an infinite stress was produced in the corner of the key-way. The reason why these shafts did not break was that all the stress formulæ in engineering were limited to happenings inside the elastic limit, and it was possible for the local yield of the metal at highly stressed points to prevent actual fracture, but the harder the metal and the less ductile it was, the more likely it was to fracture.

Having explained this in general principle, Mr. Pomeroy said he would like to give a few figures as to the increase in stress which occurs under such conditions as those applying to a key-way. One of the most interesting developments of modern mathematical science was the way in which this stress could be measured. It was interesting because it was a piece of pure mathematics taken from the brain of the man who could only think in terms of the calculus, even when he was having his breakfast, but it became applicable to practice. Personally, he was rather cold about physicists, but at the same time, every now and again the scientific gentlemen did produce something which could be applied to practice and it was for that reason that he proposed next to describe this soap bubble method for the determination of stress in irregular sections. In the first place, a plate was taken in which two holes were made. An instance which could be mentioned was a cross section of a screw propeller blade. The plate was then put on top of a shallow box and ordinary soap bubbles were blown over the two holes in the plate and a little air pressure applied from underneath. The film covering the circular hole thus became convex with an angle of about thirty degrees at the edge of the hole, whilst the other film being over a hole of irregular shape became of irregular curvature. It was found that the torsional capacity of the two sections was in proportion to the volume of the soap bubbles thus formed. By plotting contour lines from the circular and irregular shaped holes respectively it was possible to determine the stress at any point in the irregular section in terms of that in the circular section, which in turn was capable of being found by mathematical calculation.

It would be agreed that that was a very interesting piece of work but, like most scientific things, when presented to hard boiled gentlemen like his audience and himself, one was apt to wonder how near they got to the truth. Of course, there were a certain number of sections which were mathematically calculable, namely, the square, the triangle, the ellipse and the circle, and as regards these known sections it would be found that the error in the measurement of torsional capacity of the section by the means he had mentioned was of the order of .9 per cent, which was very strong evidence of the accuracy of the method. Another example related to the stress distribution in angular sections. Considering an angle section 5″ × 5″ × 1″ the stress at a point some 3½ inches away from the corner was taken as representing the mean stress in the section. This was compared with the stress at the corner of the section. With a sharp corner the ratio of the stress at the corner to the average stress in the arm was 1.8 : 1. When the radius of the corner was .05 inches the stress in the corner compared with the average stress in the arm was 1.36 : 1 and when the radius in the corner was .3 inches the stress was .491 of the average, indicating how very rapidly the stress falls off when a decent radius was put in the corner.

There was one other interesting example in connection with aeroplane propeller bosses which brought home the practical case of the key-way. The shaft was five inches diameter, bored out to 2.9 inches diameter and the key-way was 2.5 inches by one inch deep. If we plotted a curve showing the radius of the fillet as .1, .2, .3, .4 and .5 of the depth of the key-way, i.e., the radius of the fillet in terms of the depth of the key-way, it was found that when the radius in the key-way was .1 of this depth, then the stress at the corner of the key-way was five times the average stress throughout the shaft. When the radius of the fillet was .2, the stress at the corner came down to 3, when the radius of the fillet was .4 the average stress came down to 2¾ and when the radius was .3 the stress came down to 2.7. Thus a curve of this nature indicated how rapidly the local stresses in the corner of the key-way fall off when a radius was put on. The above examples are taken from "The Mechanical Properties of Threads" (Blackie and Company).

The point which interested the designing engineer was that when it was possible to obtain from production people, milling cutters, broaches and such things with round corners, to that extent it would be possible to begin to reduce weights not by 10 per cent. but maybe by 50 per cent. and then, of course, it would be possible to begin to cut costs very seriously, because after all, everything in this world was paid for by the pound. Potatoes were bought by the pound, coal was bought by the ton, gold by the carat, platinum by the ounce or gramme and, as a matter of fact, the average

high-class motor car worked out at 3s. per pound, although a cheap car might be 9d. and an expensive car 5s. per pound.

The above example was commercially one of very great interest to designing engineers because it was these eternal fights against high stresses and fatigue failures which introduced difficulties in standardisation. As a matter of fact, in his view, the only thing that was really definite about standardisation was that it meant stagnation, although every now and again the manufacturer had a bit of luck in this respect. The British Engineering Standards Association had discussed the standardisation of Stauffer lubricators for a long time and then a few years ago they standardised them at the very time that most people in the motor trade stopped using them. What was wanted, of course, was an elastic type of product which did not tie the manufacturer down in any way as to development and improvement. He objected strongly to anything which would tie down engineering manufacture to rigid limits and his plea was that all who were concerned with design should think seriously over this matter of localised stresses so that when somebody came along and said he wanted a key-way with a definite radius at the bottom corner, there would be a change from the present position of affairs when one could not even get a hearing let alone get anything done.

The rest of what he had to say, continued Mr. Pomeroy, was of a much more general nature. What he felt was that the designing engineer and the production man must have some sort of understanding about what they were after, because the main object, when all was said and done, was to make progress and, without progress, it was impossible to make profits and, without profits, it would not be possible to continue in business at all. Just in so far as capital was tied up in jigs and tools as to make it difficult to change, so to that extent would this country be very badly hampered in development and progress and his plea was that the production engineer, particularly in this country, must not worry too much about efficiency. Nobody wanted efficiency. Indeed, in his opinion, the efficient man had better be dead. What we do want is effectiveness because, if only efficiency was required, then we should not make motor car engines as we do now, but would make them in accordance with the Carnot cycle, but the result would be an engine ten times as large as anything made to-day and that would be ludicrous because it could not be got into a motor car. People often said a great deal about the need for economy in petrol consumption on motor cars, but again he contended that the ordinary man does not want economy. What was wanted was effectiveness and reasonably cheap output, but not so cheap that it was necessary to waste all our time thinking how to get the product cheaper. Personally he would be more pleased to have something for ninepence this

year than to wait next year in order to get it for sixpence, because next year he might be dead.

This brought him to the general question of the system that production engineers as a rule try to impose on the general manager. In the case of 99.999 per cent. of cost records that he had looked into, they should be viewed with the utmost suspicion. Real costs were very complicated matters and by no means related to times in decimals of a second. There was a great deal in life which depended upon luck and it had been very well put that there was no business that had ever failed from pure incompetence and that no business had ever succeeded entirely by competence. There was always a margin of the unknown, and it was here that the instinct of the real business man came in, because it was only by the application of this instinct that businesses were really made. It was necessary, of course, to have system in a business, but if he employed only half a dozen men he would not insult them by asking them to stamp a time clock. With three hundred men he might, and when it came to large undertakings in which the number of men made personal contact unhappily impossible, then it was essential to have mechanical appliances, but at the best there was hockus pockus about it and it all had to be done with a great deal of caution. What we wanted in this country particularly were men who were going to get down to the job and stick to it until they were satisfied that with the means at their disposal they had done the best they could and the first thing that arose was the necessity to stimulate output from men who were in the position of feeling that they were very possibly going to work themselves out of a job. He did not blame the working man for the attitude he often took, but when a job should take ten minutes and a man was taking fifty minutes, as an employer he wanted to know why he was making the man a present of forty minutes. Speaking as a car manufacturer, the one thing to keep in our minds in this country was American competition and he made no apology for speaking about that. The point was the essential danger of our imitation of American methods of design and production. American production schemes were characterised by having a vast population at home which could absorb more or less anything and the Americans were a sufficiently standardised people to tolerate it. Everybody in America had a motor car but there was very much less there of home life, the garden, reading, recreation and anything of that sort as compared with this country. A motor car and the movies constituted 90 per cent. of the American workmen's recreations and, although he did not wish to interfere with anybody, because this was a free country, he would not at the same time like to see the people in this country, who were essentially happy and contented, coming to the same state of mind through imitating American methods. We had got to make up

our minds that there were certain things we could not do compared with America. He did not believe we would be able to build a Ford or a Chevrolet in this country and he hoped we never would for it could only be done by our population sacrificing all the nice things it now had for the sake of running an infernal motor car up and down the road and getting no fun out of it at all. On the other hand, there were certain things which we could do. For instance, with regard to motor 'buses and aero engines, he said without hesitation, that not only could we make a better motor 'bus in this country than in America, but we could do so at fourfifths of the price. He impressed upon production engineers that they could exert all their brains and cleverness to the end of allowing for changes and progress in design even if they sacrificed five per cent. or 10 per cent. of what looked to be the ultimate reduction of cost. There were three things in this world which were certain and they were death, trouble and the certainty of change—and the capacity to change without scrapping a great deal of capital was the most potent factor in British industry.

Taking the case of the Diesel engine, Mr. Pomeroy pointed out how this had been developed by marine engineers in this country during the past ten or twelve years and had really been the means of saving the marine engine industry. Things were changing from day to day and the more capital was tied up the more difficult it is to change. There were two essential business methods, one was to have something which was so standardised that the business depended upon no change being made and the other to recognise that British business generally was in many industries dependent upon our fundamental capacity rapidly to meet the exigencies of change in life, in standards and in fashion and for our production engineers to keep this viewpoint in mind in the various capacities in which they were employed.

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(*The Discussion on Mr. Pomeroy's paper will appear in our next issue*).

WAGES DIFFERENTIA.

Further Views of Members on Wages Problems.

Mr. H. E. Weatherley (Member of Council) :—

I have read with great interest Mr. Watson's views in "The Realist," and the various replies made by the members of our Institution.

The deeper one goes into this wages question, the more it becomes apparent that the bone of contention is "How long should a job take?" and it is possible that the solution to this may be found by consulting an independent concern composed of production specialists, the formation of which I have many times considered. As the functions of this concern would be in the character of an arbitrator, the difficulties of getting both sides to agree to the appointment of a private firm would be very great, so that I would suggest that this might be brought within the scope of the Institution of Production Engineers.

Unfortunately, the mass production firms in this country are few, but I think I am right in saying that in such firms there is no dispute as to the length of time a job should take, this being due to the fact that they are able, in addition to employing very highly skilled production engineers, to equip a shop staffed with skilled operators, whose business it is to try out an operation, and determine how long it should take, before the particular piece is issued to the works for production.

In the smaller shops, however, these advantages are not obtainable, and consequently this is where the majority of the disputes arise, so a service such as I am outlining might be welcomed.

It would not, of course, be the duty of any suggested body to interfere with the district rates, or with the amount which the employer would give by way of bonus, such issues being entirely outside the scope of our Institution, coming solely within the ægis of existing organisations of employers and workers.

Their part in the scheme I have in mind would be solely to determine a time basis, or, in other words, just how long a job should take, and the procedure might be on these lines :—

In the event of a disagreement arising between management and works, as to the length of time required for some operation, application would be made to the recognised quarter (here I am suggesting the Institution of Production Engineers) for the services of an experienced and efficient production engineer, with specialised knowledge of the work which is to be performed.

After having gone into the necessary details as to the conditions prevailing in the particular works, i.e., types of machines and general equipment available, he would suggest any desirable alterations, and then determine, by demonstration and proof to both parties concerned, just how long the job should take.

This done, there should be added to this time a figure of, say, 15 per cent. or 20 per cent. to cover contingencies and fatigue factors, and then, in addition, could be added a time to cover bonus or reward for maintaining these production rates.

I should very much like to see our Institution take an active part in the forming of a service of this nature, as it is possible that employers and employees would take advantage of such a service, whereas they might not do so if it were offered by a private consultant firm.

Mr. Leonard Page :—

I am in receipt of the Journal of the Institution, No. 3, Vol. VIII., January, 1930, and was much interested in the article, " Wages Differentia."

I have had nearly thirty years' experience in various shops on systems of time payment, piecework and premium bonus and, whilst realising that accurate and careful rate fixing are conducive to success, the really essential condition is the existence of confidence and trust between the management and the operatives, only to be obtained by absolute fair dealing on either side, of which fair dealing the employer should, by virtue of his position in the community, give the first example.

It should be remembered by people in control of large numbers of their fellows that the primitive desire for a bargain is deeply rooted in human nature, and it must be recognised when fixing rates that the ca' canny procedure of operatives when working upon first production batches of parts, where the basis time or piecework price has not been definitely fixed, is not dishonesty, but just a manifestation of the bargain instinct, so much admired and looked up to in financial circles.

To deal successfully with humans one must be human oneself, and I think this applies to the rate fixer more than to any member of a works executive.